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G.R. III.

A LETTER

To Mr. EULER, Profeſſor of Philoſophy, and Member of the Imperial Academy of Sciences at *Peterſbourg*, of the Royal Society at *London*, and of the Royal Academy at *Berlin*, &c.

Read at the Royal Society,
June 3, 1779.

SIR,

I THINK myſelf highly honoured that my diſcoveries upon Phoſphori have been thought worthy the attention of the celebrated Euler.

Your Reflections upon thoſe experiments muſt have given pleaſure to the Imperial Academy, as they are ſo very curious in themſelves and ſo intereſting to the philoſophy of light and colours.

If I entertain any doubts reſpecting the concluſions you have drawn from my experiments, in favour of your own Theory, permit me to aſſure you that they proceed only from a warm deſire of having the truth firmly eſtabliſhed.

The greateſt Philoſophers have ſometimes been miſtaken; and ſhould it be made appear, in the preſent caſe, that even you yourſelf, by miſunderſtanding my meaning, have been led into an error, in regard to a very material circumſtance, upon which you ſeem to have founded your reaſoning, I hope my endeavours to diſcover truth will not only give you pleaſure, but perhaps induce you to reconſider your excellent memoir. In the mean time give me leave to lay before you a ſolution of the phoſphoric phœnomena, different from your's, which promiſes to confirm the philoſophy of Sir Iſaac Newton. But, before I enter upon thoſe matters, it may be proper, on many accounts, to ſtate a few general facts, together with ſuch ſingular phoſphoric appearances, as ſeem the moſt difficult to be reconciled with true philoſophy.

By a great variety of experiments upon Phoſphori I found, that I could, by the particular mode of preparation, make a phoſphorus exhibit any particular colour.

But while I was engaged in thoſe intereſting experiments, I recollected to have ſeen a paper of Father Beccaria's (of *Turin*) upon the ſubject of Phoſphori, in the Philoſophical Tranſactions for the year 1771, which tended to prove, by means of coloured glaſſes, that *Phoſphori emitted the ſame light as they received*.

This fact appearing ſo very extraordinary, compared with what I had at that time experienced in my phoſphoric reſearches, I ſet about trying the effect of the primitive rays themſelves upon different coloured Phoſphori, after they were refracted by a priſm, and properly intercepted, ſo that only a ſingle ray ſhould enlighten the phoſphorus. When to my great ſurprize I found, that the phoſphorus which had been prepared to give a *red light* did, after being expoſed to a *red ray*, exhibit only a very *faint* red light; and that the ſame phoſphorus did, after being expoſed to a *violet ray*, exhibit a very *bright red light*; that a *blue ray* made it ſhine, but not quite ſo brilliant; and a *green ray* ſtill leſs.

I alſo found, that a *blue phoſphorus* did, after expoſing it to a *blue ray*, exhibit in the dark a very *faint blue light*. But this was not the caſe when the ſame blue phoſphorus had been expoſed to a *red ray*; for then it ſhone with a *fine blue light*.

In conſequence of theſe and other experiments I find Father Beccaria, in a printed letter addreſſed to me, hath expreſſed himſelf, that he muſt have been deceived in his experiments; becauſe (ſays he) "*I have taken for very light tints of colours (which only* "*could be expected) what was merely a faint gradation of light, or* "*a different degree of ſhade.*" [*]

Thus

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[*] "Io debbo convenire d'eſſermi ingannato nella ſperienza mia forſe perchì ho "preſo per tinta di colori leggeriſſimi (quale unicamente ſi dovea aſpettare) ciò "che era unicamente una varia degredazione di luce, o una diverſa maniera d'ombra."

Thus far I thought this little hiſtory was in ſome meaſure neceſſary, that you might be acquainted from whence the diſcovery, which I have now been relating, took its riſe.

The cauſe of thoſe curious appearances I could not, at that time, even gueſs at, but conceived they might depend upon certain properties of light which had hitherto eſcaped the obſervation of Philoſophers: what my opinion is now upon this ſubject, will preſently appear.

It is three years ſince the ſecond edition of my book was publiſhed, in which thoſe remarkable experiments were firſt mentioned: during that period I never met with any one who had attempted to explain the cauſe of them, 'till I had the honour of receiving your memoir. And although I read it with the greateſt admiration, yet I muſt confeſs, that there are ſome things in which I cannot agree in opinion with the truly learned and excellent author.

By the following paſſage, in your account of my experiments, *viz.* * " So that any phoſphoric red body having been enlight-" ened by red rays, and afterwards *carried* into the dark," I find you have miſunderſtood me in a material circumſtance. You have conceived that the phoſphorus was carried into another room, to be obſerved, after it had been enlightened: but that was not the fact; the experiments were made in the ſame dark room, into which a beam of the ſun's light was occaſionally introduced and ſeparated by a priſm. Whenever therefore I wanted to enlighten a phoſphorus with one ray of light, I intercepted all the others. Immediately after which, an aſſiſtant ſhut out the beam of light, and at that inſtant, or nearly ſo, I viewed the phoſphorus; but my eyes for ſome time before that inſtant, were always ſhut, merely for the purpoſe of ſeeing better when the experiment required them to be open.

I have been the more particular in this account, becauſe you ſeem to lay great ſtreſs upon ſome difference in point of time. For in another part of the ſame memoir you ſay, " We need only " to diſtinguiſh carefully two moments in Mr. Wilſon's experiments.

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* Ainſi un tel corps phoſphorique rouge ayant été éclairé par les rayons rouges, et enſuite tranſporté dans l'obſcurité.

ments. [*] The firſt of which is the moment he enlightens his red phoſphoric body by the violet rays of the ſun, at which time there is no doubt but that the body muſt appear almoſt entirely deſtitute of all colour. It is only at the ſecond moment when he carries this dark body into the chamber, that it begins to ſhine with its proper colour.” You doubtleſs expreſs yourſelf here by the words, “ begins to ſhine,” as if the phoſphorus was incapable of ſhining at the firſt moment; that is, when I expoſed it to the light. In reply to this very material part, I ſhall quote two or three paſſages from my phoſphoric work, which I think are very much to the preſent purpoſe.

[†] “ With regard to the ſhells exhibiting priſmatic colours in the dark, and yet affording no other appearance in the open day, than the ſame white light they acquired by calcination, a very little conſideration may, perhaps, explain this matter, as we find it ſo exactly conſonant with other phœnomena in the natural world. The ſtars, and even the moon itſelf, are totally obſcured when the ſun is in the meridian, by the flood of light that is diffuſed over the whole of our atmoſphere. And yet, when that ſuperior light is withdrawn, how very ſplendid do the moon and ſtars appear! Now the darkneſs we produce by art, exceeds this natural one by many degrees. No wonder then, that the difference between the external light, and the cloſet we have deſcribed, is far greater than that between noon and midnight; and more eſpecially whilſt the moon continues ſhining. It is, therefore, entirely owing to this very great difference, that the priſmatic colours in the ſhells become ſo viſible in the dark, when the eye is properly prepared. So likewiſe, thoſe colours, though they actually continue to exiſt

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[†] *Page* 67 *and* 68.

[*] “ On n'a qu'à bien diſtinguer deux momens dans les expériences de Monſ. Wilſon, dont le prémier eſt celui où il a éclairé ſon corps phlogyſtique rouge par les rayons violets du ſoleil, pendant lequel il n'y a aucun doute, que le corps n'ait parû preſque entièrement deſtitué de toute couleur : ce n'étoit que dans le ſecond moment lorſqu'il tranſportoit ce corps dans l'obſcurité, qu'il *a commencé à briller* de ſa propre couleur rouge.”

“ in the open day, ceaſe to appear, immediately on being expoſed to the ſun, by the very great quantity of reflected light with which they are ſurrounded.”

“ And however ſtrange it may appear, I have ſome foundation for apprehending, that the ſplendor of the priſmatic colours in the open day, could we perceive them, is far greater than that we obſerve in the dark. This notion ariſes from many obſervations that were made during the whole courſe of the preceding experiments. For when the different phoſphori were brought from the light into the dark, the ſplendor of the colours was exceedingly more vivid in the firſt inſtant, than it appeared in the third of a ſecond afterwards. The diſappearing of this great degree of brilliancy was ſo ſudden, that I could ſeldom move the ſubſtances, which exhibited it, a few inches from the curtains, before a conſiderable alteration in its vividneſs had taken place; notwithſtanding the time in moving the phoſphori from the curtains to the convenient diſtance for obſerving, (it being about 12 or 15 inches) was not more than one ſecond.”

In another part, (page 115) where I excited phoſphoric appearances by means of the electric light, which was cauſed by the diſcharge of a large Leyden Jar, are theſe words:

“ ——Beſides, by this method of exciting priſmatic colours, I obtained another advantage, which appears to me not inconſiderable. For here, the colours may be ſeen at the inſtant, after the exploſion hath taken place; and, agreeably to a former obſervation, (meaning the above) they appear much more full, intenſe, and lively than in three or four ſeconds afterwards; or even after they have been expoſed to the light of the ſun.”

When I publiſhed the preceding obſervations I had framed no hypotheſis: conſequently there was not any inducement at that time which could influence my judgment.

Now as thoſe obſervations certainly tend to prove that phoſphori actually ſhine at the time they are expoſed to light, but are rendered inviſible by the preſence of a ſuperior light, and are only viſible when that ſuperior light is withdrawn; do not thoſe obſervations materially interfere with your manner of reaſoning, which

which is entirely founded upon the different effects taking place at the two different moments you have marked?

That this is the true ſtate of the caſe will appear more fully by the following quotation taken from the *two laſt pages* of your memoir.

* “ But to come to what relates more particularly to theſe new
“ experiments, I have demonſtrated that it is abſolutely falſe,
“ that

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* “ Mais pour ce que regarde plus près les nouvelles experiences, j'ai démontré,
“ qu'il eſt abſolument faux, que les corps opaques nous déviennent viſibles par des
“ rayons reflechis comme on s'étoit généralement imaginé autrefois, mais qu'il faut
“ abſolument, que les moindres particules qui ſe trouvent dans la ſurface de ce corps
“ ſoient miſes dans un certain mouvement de vibration plus ou moins rapide ſelon
“ que la couleur du corps l'exige, attendu qu'à chaque couleur il repond un certain
“ nombre de vibrations achevées pendant une ſeconde. Car alors ce même mouvement
“ produit des ſemblables vibrations dans l'ether environnant, d'où réſultent des rayons
“ de la même couleur. Par là il eſt clair que les rayons, par leſquels nous voyons
“ les corps opaques, ſont engendrés dans leur propre ſurface conformement au degré
“ d'élaſticité dont les moindres particules y ſont douées. Or pour mettre ces parti-
“ cules dans un tel mouvement de vibration, il faut que des rayons de lumière y
“ tombent, qui par leur action les excitent à un tel mouvement; de la même
“ manière qu'un corde de muſique en répos étant expoſée à un ſon aſſés fort com-
“ mence à trembler et à rendre elle-même un ſon qui repond à ſon degré de tenſion.

“ Cela poſé un corps phoſphorique rouge tel que Monſ. Wilſon a examiné, ne
“ nous ſauroit devenir viſible, qu'en tant que les moindres particules dans la ſurface
“ ne ſoient excitées à un mouvement de vibration qui convient à ſa propre couleur.
“ Ce ſeront donc ſans doute les rayons rouges, qui ſeront les plus propres à imprimer à
“ ces particules un tel mouvement de vibration, qui par la nature phoſphorique de
“ ce corps ſe conſerveront encore pendant quelque tems après que les rayons incidens
“ auront ceſſé d'y agir, mais d'une manière beaucoup plus foible que pendant que
“ les rayons rouges y ont agis actuellement. Voyons à préſent quel effet les rayons
“ violets doivent produire ſur ce même corps phoſphorique rouge, et d'abord il eſt
“ évident qu'ils ne ſçauroient porter ſes moindres particules à un mouvement de
“ vibration à cauſe de la contrarieté qui regne entre les vibrations des rayons violets
“ et celles que les propres particules du corps ſont diſpoſés à reçevoir. Par cette
“ raiſon tout l'effet de ces rayons violets ſe reduira à pouſſer les particules du corps
“ à un certain degré de tenſion ſans leur imprimer un mouvement actuel. Donc
“ auſſitôt que le corps ſera retiré de l'action de ces rayons, ſes moindres particules
“ commenceront à ſe degager de leur étât de tenſion, et reçevront le même mouve-
“ ment de vibration qui eſt propre à leur nature, et par tant elle répandront des
“ rayons rouges, qui ſeront même plus forts, à cauſe du haut degré de tenſion, que
“ ſi le même corps avoit été expoſé aux rayons rouges. Enfin par la nature des
“ corps phoſphoriques ce mouvement de vibration pourra durer plus ou moins long
“ tems ſelon le degré dont ces corps ſeront doüés de la qualité phoſphorique.”

“ that opaque bodies become viſible to us, by reflected rays; as
“ was generally imagined before. But that it is abſolutely ne-
“ ceſſary that the ſmaller particles in the ſurface of bodies muſt
“ be put into a certain movement of vibration, more or leſs
“ rapid, according as the colour of the body requires: ſince to
“ each colour there correſponds a certain number of vibrations to
“ be performed during a ſecond: for then this ſame movement
“ produces ſimilar vibrations in the ſurrounding æther. From
“ thence it is clear, that the rays, by which we ſee opaque bodies,
“ are *engendered* in their proper ſurfaces, conformably to the degree
“ of elaſticity with which their ſmaller particles are endued.
“ Now to put theſe particles into ſuch a movement, rays of light
“ muſt fall on them, which by their action may excite them to
“ ſuch a movement. In the ſame manner as a muſical chord at
“ reſt being expoſed to a ſound ſufficiently ſtrong, begins to
“ vibrate; and to give a ſound which correſponds to its degree of
“ tenſion. This being laid down, a red phoſphorical body, ſuch
“ as Mr. Wilſon has examined, can only become viſible to us in
“ conſequence of the ſmaller particles in its ſurface, being excited
“ to a movement of vibration which anſwers to its proper colour:
“ therefore, doubtleſs, the red rays will be the moſt proper to com-
“ municate to thoſe particles ſuch a movement of vibration, as
“ from the phoſphorical nature of this body, will ſtill continue
“ for a certain time, after that the incident rays ſhall have ceaſed
“ to act upon it; but in a manner much more feeble, than whilſt
“ the red rays were immediately acting upon it.

“ Let us now conſider what effect the violet rays ought to pro-
“ duce upon this ſame phoſphorical body. In the firſt place it is
“ evident that they cannot diſpoſe its ſmaller particles to a move-
“ ment of vibration, upon account of the contrariety which reigns
“ between the vibrations of the violet rays, and thoſe which the
“ proper particles of the bodies are adapted to receive. From this
“ reaſon the whole effect of theſe violet rays will be reduced to
“ forcing the particles of the body to a certain degree of tenſion;
“ without communicating to them any actual movement (of vi-
“ bration). But as ſoon as the body ſhall be withdrawn from the

“ action of thoſe rays, its ſmaller particles *will begin to diſengage them-*
“ *ſelves from their ſtate of tenſion*; and will receive that movement
“ of vibration which is proper to their nature: and in conſequence
“ will emit red rays: which will be even ſtronger, upon account
“ of the high degree of tenſion, than if the ſame body had been
“ expoſed to red rays. Laſtly, from the nature of phoſphorical
“ bodies, this movement of vibration will be enabled to continue
“ during a longer or a ſhorter time, according to the degree of
“ phoſphorical quality, with which the bodies are endued.”

Thus far Mr. Euler.

LET us now ſee how far thoſe ſingular phoſphoric phœnomena may be explained upon other principles:

When a beam of the ſun's light is let fall upon any coloured phoſphorus, the ray, which is of the ſame colour with the phoſphorus, will be always moſt reflected: while the others are abſorbed, in proportion to their difference in the order of colours from that reflected ray.

For inſtance, if the beam fall upon a red phoſphorus, the red ray will be moſt reflected, and the other rays abſorbed, in proportion to their difference from the red one.

Again, if it be let fall upon a violet phoſphorus, the violet ray will be moſt reflected, and the other rays abſorbed in like manner.

Now theſe rays that are ſo abſorbed will, by refractions and reflections within the phoſphoric body, excite thoſe vibrations which cauſe it to emit its proper light.

For example, the *violet rays* being abſorbed in the red phoſphorus will, by refractions and reflections, excite vibrations, and cauſe it to emit a *brilliant red light*, which is the proper colour of the phoſphorus.

In like manner the *blue rays*, which are leſs abſorbed than the violet, will excite a red light not quite ſo brilliant, and the green rays leſs brilliant ſtill. So, for the ſame reaſon, the *red rays*, being abſorbed in the violet phoſphorus, will excite vibrations, and cauſe it to emit a *brilliant violet light*, which is alſo the proper colour of the phoſphorus.

Laſtly, the *yellow rays*, being abſorbed by the ſame violet phoſphorus in like manner, but in a leſs degree, will excite vibrations, and cauſe it to emit a violet light, but not quite ſo brilliant. And the *green rays*, being ſtill leſs abſorbed, will excite weaker vibrations, and cauſe the violet phoſphorus to emit a fainter light.

All which effects ſeem to be perfectly conſiſtent with Sir Iſaac Newton's philoſophy of light and colours *, and admit of an eaſy and natural ſolution, without having recourſe to any other ſuppoſed properties of light, not known to that truly great Philoſopher.

I am, with the greateſt reſpect,
Learned SIR,
Your moſt obliged humble ſervant,
B. WILSON.

Great Ruſſell-Street, Bloomſbury,
London, May 25, 1779.

Note, The learned Mr. Beguelin, I find, has preſented to the Academy at *Berlin*, his opinion on my work upon Phoſphori. It is inſerted in the 7th vol. of the new *Berlin* Memoirs, where he expreſſes himſelf in the following words:

† "Mr. Wilſon, from an apprehenſion of ſhaking the doctrine "of the immutability of the coloured rays, explains the obſer- "vation of the 7th experiment by the ſuppoſition, that the ſolar "rays, of what kind ſoever, have the power of kindling a light "flame in the parts of Phoſphori. And that this flame has the "colour of the phoſphorus itſelf, and not the colour of the kind- "ling ray. But this explication does not afford a reaſon why the "weaker rays, ſuch as the blue and the violet, excite a ſtronger "flame than the red or the yellow rays."

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* *Part 2d, Book* 1, *prop.* 10.
Part 3d, Book 2, *prop.* 9. *and* 10.

† "Monſ. Wilſon, dans la crainte de porter atteinte à la doctrine de l'immuta- "bilité des rayons colorés, explique l'obſervation de l'experience VII. par la ſup- "poſition que les rayons ſolaires quelconques ont le pouvoir d'allumer une legere "flamme dans les parties des phoſphores, et que cette flamme a la couleur propre "au phoſphore même, et non la couleur du rayon allumant; mais cette explication "ne rend pas raiſon pourquoi les rayons les plus foibles, tels que les bleux et les "violets, excitent une plus forte flamme que n'excitent les rayons rouges, ou les "jaunes."

I think that this difficulty of Mr. Beguelin's, which might ſeem to contradict, or at leaſt to weaken the ſyſtem of Sir Iſaac Newton, is already compleatly removed in the above memoir.

To the proofs which I have already given in ſupport of the opinion that Phoſphori ſhine by a flame kindled within their ſubſtance, may be added ſome very curious and ſtriking experiments made at *London*, by the celebrated Monſ. L'Abbé Fontana, Phyſician to the Grand Duke of *Tuſcany*.

He has proved by direct experiments, that the Phoſphorus of *Bologna*, that of Canton's, and that made with lime, being incloſed in a veſſel full of common air, diminiſhed that air ſenſibly, and rendered it phlogiſticated. This he verified by nitrous air. Now it is certain, as he reaſons, in conſequence of theſe experiments, that thoſe effects are always produced by ſubſtances in combuſtion, however inſenſible and ſmall their flame may appear to be. The difference is only between the more or the leſs. The effects of the flame are the extrication of the phlogiſton, the diminution and the phlogiſtication of the atmoſpherical air. It is not difficult to excite an actual flame in the greater part of bodies which actually produce phlogiſton, only by augmenting a little the force of this principle, which cauſes the extrication of it.

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